

# Land ecosystems

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## 1. Introduction

### Background

What will the landscape look like in which our children and grandchildren live in 2050? What trends do we see today and how will our landscape and its productivity change if today's development continues at the current speed or even accelerates? This report represents, as is the case with any future projection, an estimate on the basis of current knowledge; an attempt to draw as plausible a picture as possible.

The most important impacts that ecosystems are exposed to nowadays include the following:

- Human-induced land-use changes
- Changes in the composition of the atmosphere (CO<sub>2</sub>, nitrogen compounds)
- Climate changes (warming, changed precipitation patterns, storms)
- Accumulation of active agents (pesticides, hormones, general reactive substances)

The possible impacts of these changes are:

- Loss of biological diversity and entire biotic communities
- Change in land-cover types (forest, arable land, grassland, settlement, etc.)
- Loss of soil matter and soil quality
- Changed ecosystematic benefits to humans

Any assessment of the future development of the natural resources of a country necessar-

ily begins by studying the current state and its historical development. In the case of land ecosystems (water-related systems are dealt with in the Water management chapter), the areal distribution of land-cover types over the course of time is the best starting point. Astonishingly, such data have only recently been available.

In Switzerland, the first vague estimates of forest area go back to the year 1840. Entire mountainsides were clear-cut at that time. The first Forest Act of 1876 restrained the rampant deforestation and brought about the preparation of the first forest inventories. Later on, the focus of interest was mainly on immediately required resources. Thus, during the World Wars, people were concerned with the potential of their own agricultural production and the suitable areas for this purpose. The methods used have also not been constant over time. It is, for instance, difficult to define what is and is not a forest. Are groves, windbreaks or emerging young-growth forests on former grassland included or not? The historical development of different land-cover types since 1900 is represented in figure 1 as an estimation based on historical data sources.

The first land-use statistics of Switzerland that were based on aerial photographs, and were therefore relatively precise, were made in the years 1979–1985. Further statistics exist from the years 1992–1997. A third update has been in progress since 2005 (conclusion by 2013). The changes between the first and the second land-use statistics are shown in Table 1.

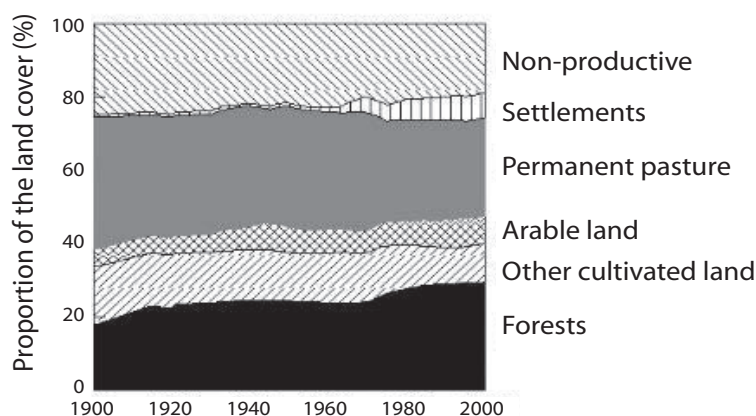


Figure 1: Estimate of the development of land-cover types in Switzerland between 1900 and 2000<sup>1</sup>

Table 1: Land-cover types in Switzerland. 74 basic categories were grouped into 4 main categories.

Land-use and structural categories	area in ha (% of total area)		changes between surveys	
	1979–1985	1992–1997	ha	% (100%=1979/85)
Settlement and traffic area	246'098 (5.97%)	278'772 (6.76%)	32'674	+13.3
Agricultural area	1'572'091 (38.15%)	1'523'930 (36.98%)	-48'161	-3.1
Forests and woods	1'252'815 (30.40%)	1'269'825 (30.81%)	17'010	+1.4
Non-productive areas and vegetation <sup>a)</sup>	1'050'044 (25.48%)	1'048'521 (25.45%)	-1'523	-0.1

<sup>a)</sup> Wetland habitats (inventory areas) are contained in this category (area sizes according to federal inventories for the protection of upland and low moors).

At the time of the first survey (1979–1985), agriculture, with 38.1%, accounted for the largest proportion of the about 41,290 km<sup>2</sup> of land area in Switzerland. The proportion of forest and other wood types amounted to 30.4% of the land area. Settlements, industry and transport networks covered just under 6% of the land area, 25.5% were so-called unproductive areas: rocks, glaciers, lakes and rivers. It can be roughly said that the forest and settlement areas have increased by about 1.2% within the 12 years (1992–1997) at the cost of agricultural area, although this trend has accelerated considerably in the recent past. In the second survey, forested areas covered about 31% of the land area. The strongest increase could be noted for shrub forests in the alpine region. The 3% loss of agricultural land seems small but hides the fact that cultivated land disappears on a large scale (3% corresponds to the disappearance of the entire canton of Obwalden).

Meadows and pastures have given way to forests at marginal yield locations and primarily to urbanisation in areas of high-yield agriculture. Urbanisation and traffic areas together increased by 13.3% in only 12 years. In this period, 7,5ha of agricultural land were transformed into settlement and traffic areas per day.

The following considerations and scenarios should be appreciated against this background.

The significance of forest areas increases, that of grassland decreases, and glaciers retreat from large areas in high alpine areas. The development of the urban area and of agriculture is dealt with in separate chapters. Here, the Land ecosystems chapter focuses on:

- Forest ecosystems
- Meadows and pastures (extensively used grassland)
- Wetland habitats (moors, meadows, banks)

The impacts on fauna are presented as a topic covering all three land-cover types.

The historical developments that led to today's state are briefly outlined in order to subsequently focus on the future. Emphasis will be put on the climate variables temperature and precipitation, and for each, continuous development and extreme events will be distinguished. The text is divided into the following sections:

- Biodiversity (species loss, habitat loss, biotic interactions)
- Natural hazards and living-space security (erosion, floods, slope instabilities)
- Ecosystem benefits and products (wood, food, carbon stores)

## Overview

The species composition of the ecosystems in Switzerland will change in the long term, since the species react differently to climate change. Many of these changes are irreversible. On the one hand, hitherto existing species will disappear, on the other hand, foreign plant and animal species will immigrate from warmer regions. Thus, the Swiss flora and fauna will approximate even more closely that of lower-lying and more southern regions. Species bound to cooler living conditions will have to move to higher elevations in the alpine region. There, however, they will be strongly restricted in area due to the topography and in the extreme case may lose their habitat entirely. Species with little opportunity to spread out will be particularly affected by the warming. Climate change as well as land use will have an impact on biodiversity in the coming 50 years.

The resistibility of the vegetation and therefore the security of our living space can be strengthened by a broad diversity of species and sustainable use of the natural ecosystems. More frequent and more intense extreme events can severely disturb ecosystems locally so that they may lose their protective effects, at least in the short term. However, the mean changes calculated for 2050 will not substantially endanger living space security in Switzerland.

Land ecosystems not only fulfil important functions like protection against natural hazards but also provide economically relevant products such as wood, food and clean water. This benefit will be primarily affected in the future by combined effects, such as high temperatures in combination with low precipitation. The productivity of forests and permanent grassland will change considerably: At higher elevations, a higher productivity will dominate due to the warming, at lower elevations, it will suffer due to summer drought. A pronounced water shortage in summer in combination with high temperatures – as for instance in 2003 and in a milder form in July 2006 – will strongly limit productivity. In years with sufficient humidity, the warming may possibly prolong the growth period, although

the genetically determined pattern of development of many crops, as well as of domestic flora, allows for little scope for change (<2 weeks).

Water availability will become even more important in the future than today, although valleys and hill country will be most affected. The management of land ecosystems will have to adapt to the changed environmental conditions. Thus, the significance of high-altitude areas as ecological buffer zones for livestock husbandry will increase.

## Links to other topics

### Water management

- Groundwater level, demand for irrigation water for permanent grassland
- Production losses due to water shortage

### Agriculture

- Conflicts about water use, highly mechanised cultivation methods and possible increased use of fertiliser and pesticides
- Alpine region as a rediscovered area for cultivation

### Energy

Quality of power station catchment area (slope stability, erosion)

### Health

- Immigration of foreign species (neophytes) that can cause allergies and asthma (e.g. *Ambrosia artemisiifolia*)
- Calamities due to the increase in natural hazards

### Tourism

Failure of protective measures in the alpine region

### Insurance

Question about insurance cover in the case of failure of the protective function of land ecosystems due to extreme weather events (security of living space)

## 2. Biodiversity

**In Switzerland, the living space is strongly shaped by altitudinal zonation, which has led to the formation of vegetation belts. With climate change, these belts will move upwards but the species composition within the belts will also change. Particularly at lower elevations, this will mean a loss of hitherto existing species and the immigration of up to now foreign plant and animal species from warmer regions.**

Even though Switzerland, with a land area of 41,290 km<sup>2</sup>, is relatively small and is not situated at the sea (which is why the diverse coastal zone flora and fauna is missing), the number of species is similar to many other, much larger European countries. The relatively high diversity of species is due to the considerable altitudinal gradient, the geological diversity, the richly structured cultivated land that has been farmed traditionally for a long time, and the large number of natural habitats.

The distinct vegetation belts in Switzerland represent a reaction of fauna and flora to altitudinal zonation. These altitudinal zones are shaped by their specific climate and the topography. While the topography will hardly change in the short term, the climatic zones will tend

to move upwards with warming. Thus a new combination of topography and climate results. The question of shifting and changing vegetation belts is therefore important with regard to further changes.

Due to their relative size, *vertebrates* depend to a large extent on habitat use and structure, as well as to direct use by people (hunt, pest control, etc.). This will – as with invertebrates – largely conceal the impacts of climate change. In particular with regard to mobile animals (e.g. birds), it can be assumed that immigration from warmer regions will remain relevant in the long term. Furthermore, the already currently observed trend that bird species that were once migratory now overwinter in Switzerland will probably continue, as a result of the favourable climate.

### Development up to today

**Since the last ice age, species have always naturally immigrated from warmer regions into Switzerland. In settlement areas at lower elevations, immigration is faster due to human influences, while ecosystems at higher elevations change only slowly.**

Already today, a large proportion of the fauna and flora of cities and waterbodies are foreign species. The immigration of foreign animal species can take place very quickly due to their mobility. With regard to vertebrates, humans almost always play a major role. The spread of foreign species either happens on purpose or unintentionally due to the transport of goods.

The fact that the dominating forest belts in particular will move upwards with general warming is undisputed<sup>2</sup> and can be verified for the late and post-glacial development.<sup>3</sup> It is assumed that this shift could take a long time and that today's tree species distribution will have centuries to adapt to the changed conditions. The small number of observed species shifts in the range of the tree line, point to the fact that such reactions take place particularly slowly at high elevations.<sup>4</sup>

In Switzerland, the number of species has increased since the ice age as a result of the

constant immigration of foreign species. Due to warming and the increasing mobility of people, this trend will even accelerate (fig. 2). However, new species rarely or with long lag times intrude into the present domestic vegetation and can mainly be found in disturbed habitats.

Domestic species increasingly become extinct for different reasons. Either they cannot tolerate the warming anymore, they are displaced by newcomers or suppressed by more strongly dominating domestic species. The latter is true for instance for forests, where the growth of most tree species has accelerated in the past 200 years with simultaneous decrease in use (fig. 3). This has led to denser plant stands and therefore to a decrease of sun-loving species. A similar development could be observed in the wetlands at medium elevations, which hardly change with decreasing precipitation but do react to increasing nutrient input.

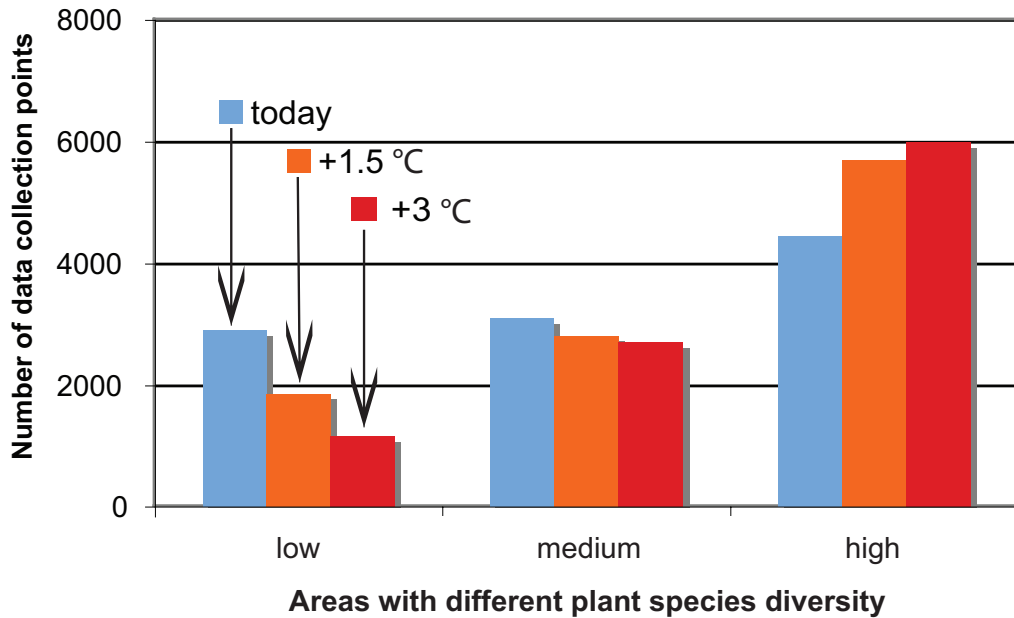


Figure 2: Projected changes in the number of plant species in Swiss forests due to climate change (simulation study, simplified).<sup>5</sup> With increasing temperature and simultaneous slight increase in precipitation (+15% in the model; according to current OcCC projections, precipitation will decrease), the number of species-poor areas will decrease, the number of species-rich areas will increase. The data collection points are random samples collected in the forest area at the intersection points of a 1-km grid mapped over Switzerland. The number of species relates to an area of 200 m<sup>2</sup>.

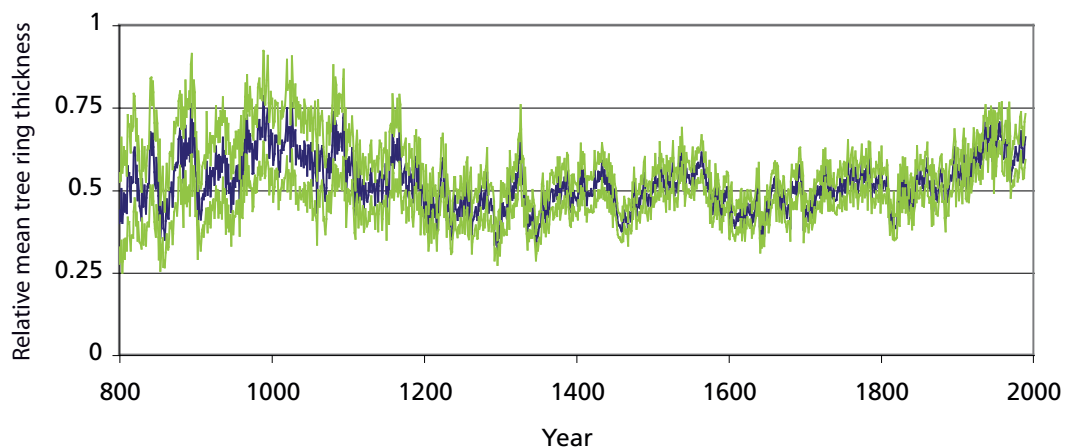


Figure 3: Average increase in thickness of the naturally occurring tree species in the alpine region up to 1993.<sup>6</sup> Since 1816, the tree ring width has steadily increased. The strong fluctuations (uncertainties) before the year 1200, are attributed to the lack of such old wood samples (low replication). Violet line: mean values. Green line: standard deviations.

## Future

**Climate change as well as land use will affect biodiversity in the coming 50 years. In general, the fauna and flora will increasingly approach that of regions at lower elevations and situated more to the south. It is difficult to estimate how many species will be lost or newly immigrate.**

The immigration of foreign species into Switzerland will drastically accelerate in the coming 50 years due to the rapid temperature increase. Due to climate change, flora and fauna will even more strongly approach that of lower elevated and more southerly regions. In addition, animal and plant species (so-called neozoa and neophytes) from all over the world reach Switzerland due to trade (e.g. ornamental plants) and the mobility of the population. Many newly immigrated species do not at first have any enemies or illnesses and tend to population explosions.

forests, abandonment of wood pasture, increase in game population).

Based on today's knowledge, not only the climate but also primarily the change in land use will strongly affect biodiversity. Utilisation will likely concentrate on favourable locations in valleys (agriculture) and well-accessible forests, due to the liberalised agriculture and forestry policy. Increasing energy prices could reverse this trend due to energy wood use. Many cultural relicts (e.g. structural elements in the landscape) of past centuries will disappear. In the Alps and the Jura, agriculture should be able to survive with the



Figure 4: Since the 80s, *Mantis religiosa* has immigrated into Switzerland from the southwest (Jura) and Alsace. In the summer of 2006, egg masses were found in a forest clearing in Fricktal (Canton Aargau).

(Source: Peter Duelli, WSL)

As the time until the year 2050 is very short for most ecosystems, the general warming trend will lead to an inevitable uncoupling of “climate requirements” and actual habitat climate. This will lead to a gradual shift in the species pattern of the existing flora and fauna. Certain species will be stimulated, others will be repressed. These processes are superimposed on current land-use changes, such as the retreat of agriculture and forestry from mountainous areas. An additional factor affecting these processes lies in historical changes in land utilisation. The consequences of these changes are only noticeable today, although they took place 100 years ago (e.g. age structure of

aid of direct payments, especially in important tourism regions. There will also be a gradual shift from today's propagated multifunctionality of the forest area to a subdivision of areas according to their respective prioritised forest functions: subsidised care for protection forests and specific forest reserves, forests without commercial use of wood, as well as managed forests, in which a profitable use of wood is possible. A further expansion of settlement areas and an increase in traffic can be anticipated, which will mean the loss of near-natural areas, as well as the further fragmentation of the landscape. The habitats of animals and plants will thus become smaller or disappear.

In the alpine region, species bound to cooler living conditions will be displaced to higher elevations. There, however, they will have a smaller total area at their disposal due to topographic reasons. Thus, the vegetation belts will not only move upwards but will also become restricted in area,<sup>2</sup> though different species competition may change this trend (slow down or accelerate), in particular for trees. Plant species carried by rivers and streams will immigrate the most quickly, namely in the warmest regions (waterbodies in Ticino, Rhine at Basel, Rhone at Geneva). However, the spread to higher elevations will be restricted by the delayed adaptation of the species to the climate. In the mountains, primarily pioneer species on virgin soils will be able to quickly follow the trend. Heat-loving neophytes will also spread in forests, which means that garden plants available in stores may spread over large areas in the Ticino and the midlands.

In Switzerland, except for the southern part, a decrease in the number of species is particularly expected in low moors. This will become even stronger if precipitation decreases and the extension of these habitats decreases due to water shortage. With regard to this process, the upland moors in Switzerland are in a special position. The higher temperatures and the longer dry periods endanger the moss cover and enable species uncommon in upland moors to invade these habitats. This is unwanted because

it represents an ecosystem modification and species poverty represents a typical characteristic of upland moors. The displaced species are specialists that are unable to settle in any other habitat.

Warming will above all exert pressure on those species that are less mobile or depend on less mobile species as food or host. Mobile species can move to cooler habitats, which is simpler in the mountains than in the lowlands. Nevertheless, warming and land-use change will mean the extinction of many species, particularly in the Alps and in the Jura. Especially endangered are species with very isolated occurrences (endemites) and those that cannot move further upwards.

Cold-loving species inhabiting the tundra (mountain hare, snow grouse) will, for the present, find a larger habitat on mountains with a large alpine and nival zone, thanks to the spread of the vegetation cover but will become extinct on small, lower lying rocky outcrops. Cliff-dwelling species of southern origin (ibex, wallcreeper) will expand their habitats upwards or have already done so (rock partridge) (see fig. 5).

Also with vertebrates, the mobile forms (birds, large mammals) will be able to react more quickly to climate change. However, any upward shift of the habitat means a net loss of area, since the land area decreases with height. Reliable data in this regard are available for the population



Figure 5: Cold-loving species inhabiting the tundra, such as the mountain hare will, for the present, find a larger habitat in mountains with a large alpine and nival zone thanks to the spread of the vegetation cover. However, they will become extinct on small, lower lying rocky outcrops at lower elevations. (Source: Martin Merker)

Cliff-dwelling species of southern origin, such as the ibex, will expand their habitats upwards or have already done so, provided the mountains are high enough. Otherwise, the local populations might collapse. (Source: Thomas Jucker)

change of birds. As figure 6 shows, in the past 15 years, a decrease in the number of species on cultivated land but an increase in forests could be observed. This trend goes in the same direction as the spatial development of land-cover types. (fig. 1, table 1). For all organism groups, it is true to say that short-term, spectacular changes are less likely, and that these changes are restricted to single species. This is shown, for instance, in fig. 6 by the “Swiss Bird Index” of all bird species, which remains practically constant.

Overall, the number of species in Switzerland is increasing steadily in spite of increasing loss of species, since immigrations are considerably more numerous than cases of extinction.

However, in the overall evaluation, the losses have to be given more weight because many of these species are becoming entirely extinct, that is worldwide, while the immigrating species often have their main distribution area in the Mediterranean, sometimes even on other continents.<sup>7</sup>

The shift from integrative land use (everywhere a bit of everything) to regional segregation (protection of species here, intensive production there) that is emerging in politics is equally important for the changes in biodiversity in Switzerland. This shift is scientifically and politically controversial, and signifies a change in society’s perspective regarding this problem.

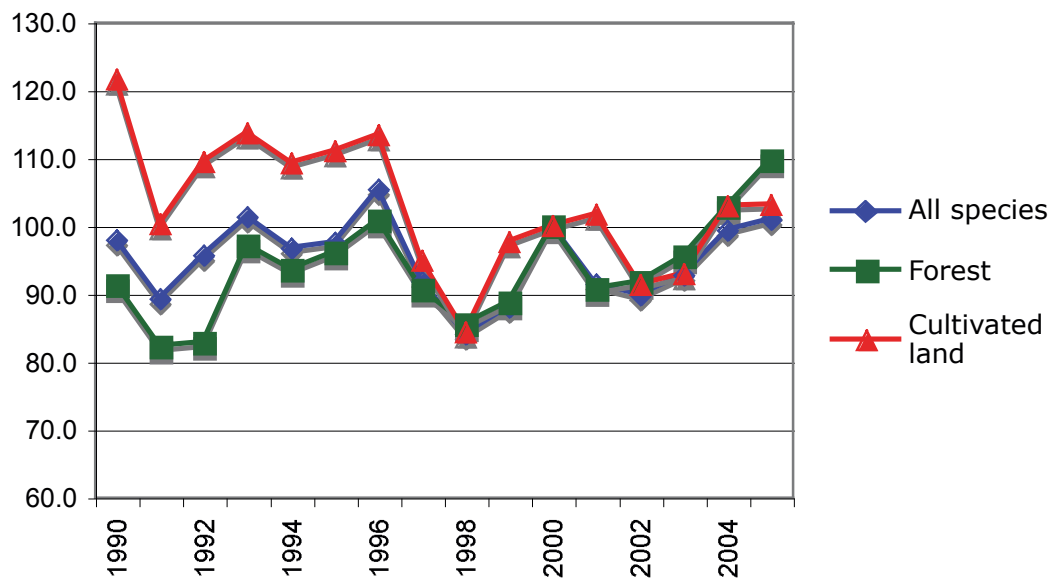


Figure 6: Development of the “Swiss Bird Index” (the SBI represents the number of sedentary bird species in different landscape types) over the past 15 years. In cultivated land, variety is decreasing, in forests increasing, and overall constant, if all bird species are considered. (Source: © Swiss ornithological station Sempach)

## Measures

**Direct measures for the preservation of endangered species are difficult to achieve. The best protection is offered by maintaining the habitat, which also includes the maintenance of small-scale, diversified land use.**

The traditional measures for species and habitat protection for preserving species diversity are also quite suited to counteracting future developments. What is desirable is to have various types of land use side by side as well as a comprehensive system of species protection (including reserves) and specific species maintenance, depending on region and cultural characteristics.

The strong intensification of land use (agriculture, settlement and commercial) caused massive species losses in the last century that were not compensated for by partial extensi-

fication (mostly reforestation). Counteracting such losses is also worthwhile and a priority in relation to climate change. The situation presented by newly immigrating species is more difficult. Among these, there will be species that are harmless and whose spread is the logical consequence of the changed environmental conditions. Others, such as aggressive neophytes, neozoa and new pathogens, which endanger biodiversity, have to be systematically regulated. Recognising such species at an early stage is difficult and an area for ecological research.

## 3. Natural hazards and living space security

**With increasing frequency and intensity of extreme events, ecosystems in Switzerland may locally be strongly disturbed and therefore lose their protective function, at least in the short term. The mean changes in climate to 2050 that are expected based on climate models will have comparably less effect on ecosystems. The risk to living space security and the integrity of ecosystems mainly results from climatic extreme events and the unadapted use of sensitive landscape types (e.g. non-native species composition of forest and changed use of mountain pastures but also introduction of pollutants into unused ecosystems).**

The different landscape types and habitats in the mountainous area of Switzerland fulfil a multiplicity of important functions: Every kind of closed vegetation cover protects the soil, stabilises slopes and protects against erosion. Forests play a particular role in protection against avalanches and rockfall, and enhance the ecosystematic water storage. At the same time, vegetation is a provider of resources, and serves as a place for recreation and sport. These important functions are inseparably linked to the resilience, stability and dynamic adaptability of ecosystems, in particular of forests. Thereby, apparently unimportant organisms play a role in ensuring living space security. The interaction between these countless components ultimately

determines the vulnerability of the systems to changes in use or climate. The use of ecosystems for agricultural and forestry operations but also for tourism has a much larger potential to change the protective functions within the time frame of a few decades than the future mean changes in temperature and precipitation. An accumulation of extreme climatic events can cause rapid changes in natural ecosystems and thus carries the risk of an at least temporary loss of functionality. In addition, the increasingly dense use of the landscape by humans leaves less and less room for major natural hazards (e.g. floods), which is why they are becoming appreciably stronger and are therefore also causing more damage.

## Development up to today

**Up to now, temporary losses of living space security have mainly occurred due to extreme events and settlement activity in hazard zones. However, the continuous change in the type of land use and the input of nutrients and pollutants from the air have made some ecosystems more vulnerable to further climatic disturbances. On the other hand, single changes, such as the increase in forest area, also show positive effects: Forests stabilise steep slopes much better than all other ecosystem types.**

In Switzerland, forests and extensively used grasslands have undergone a great change in the past 150 years. In the past, every patch of land was assessed from the perspective of its productive benefit to humans. Thus, wetlands were drained, forests were oriented towards increasing the yield of qualitatively first-class wood, and meadows and pastures were also cultivated in rough terrain. In doing so, the issue of ecosystem integrity and also of the living space security linked to this was of secondary importance for a long time.

Today, many of these areas are not economically interesting anymore. However, the significance of intact vegetation cover for living space security has increased at many locations. This is because it is currently at many of these locations that the tourist infrastructure and settlement area profit from protection forest (both have advanced into potential hazard zones). Mountain pastures become overgrown (are lost as special living space and resources) and rough terrain is not used anymore. On the other hand, the pressure of the leisure society increases on almost all vegetation types.

These human influences have, in addition to climatic changes, affected the vegetation and in this way also the protective function against natural hazards linked to it. More forest usually increases the water storage capacity of the soil, improves slope stability and protects against erosion. Depending on the topography, more forest also protects from avalanches or rock-fall. Running counter to this is the increase in extreme events, partly leading to floods and landslides, which could not be absorbed by the natural buffer effect of the vegetation. The increased incidence of storm damage has temporarily, strongly reduced the living space security in the areas concerned (e.g. the Vivian, 1990 and Lothar, 1999 storms). A greater weakening of the ecosystems due to extreme events has often occurred at locations where the topographic

conditions had already required larger human interferences anyway in order to make modern human life possible, e.g. in alpine valleys or in the vicinity of rivers. To some extent, heavy precipitation has also occurred in combination with geological conditions that exceeded the retention capacity of any vegetation type. Extreme precipitation events led to the sliding off of entire forest sections (e.g. in central Switzerland in the summer of 2005).

However, temporary reductions in living space security have also occurred in forests where dryness, in combination with high summer temperatures and intensified insect attack, led to the extensive dying of trees (e.g. bark beetle epidemic after Lothar and in the dry summer of 2003, pine forests in the Valais;<sup>8</sup> see figs. 7 and 8). Also here, in addition to climatic influences, the type of forest utilisation in the last 100 years may have played a role. Deciduous trees, most notably the downy oak, quickly settle released areas and were therefore largely able to replace the function of pines up to now (see fig. 8).



Figure 7: The combination of enhanced winter windthrow and warmer summers results in a bark beetle population explosion. (Source: Christoph Ritz)



Figure 8:  
At lower elevations in the Valais, the combination of abandoned land use (wood pasture) and warmer, drier summers leads to the rapid modification of pine forests into downy oak forests. (Source: Roman Zweifel)

## Looking ahead

**Further locally and temporally limited loss of protective functions of ecosystems is to be expected due to the predicted increase in the frequency of extreme events. This does not represent a problem for unused parts of the near-natural landscape far from urban areas, since new niches for plants and animals are generated by this dynamic. However, if settlement and transport networks are affected, these changes have disastrous effects.**

50 years is a short time period for vegetation and in particular for forests because changes appear with some inertia and delay. Up to the year 2050, the mean (!) predicted climate changes hardly represent a substantial danger for the protective functions of vegetation cover and the living space security linked to this in Switzerland. However, more frequent or pronounced extreme events (heat, drought, fire, heavy precipitation, storms) can have massive effects locally and can abruptly change ecosystem integrity (such as after a forest fire or a heavy insect attack). Such processes will become more likely the more rapidly the climate changes and the more strongly vegetation is already in a process of change as a result of the general climate trend.<sup>9</sup> However, such scenarios of a sudden build-up of harmful effects (e.g. insect calamity as a result of drought) are hard to predict.

The effects of climate changes (in combination with human influences) for which there are

empirical data can be estimated more reliably. Based on today's knowledge, stronger than average effects of climate change are to be expected for the following ecosystems by 2050:<sup>10</sup>

- ecosystems that are far from their natural form, composition and functionality due to human interference, e.g. forest monocultures with non-native species or over-cultivated (e.g. over-fertilised and thus species-poor) grassland
- ecosystems that are situated in climatic border zones, e.g. in melting permafrost areas, at arid sites on the border of desertification, at only slightly wet wetlands and in the vicinity of the upper timber line
- ecosystems in which land use has counteracted the natural climate-induced development of the past decades (e.g. at locations where

the upper timber line was kept artificially low by mountain pastures, the forest may advance again very quickly in the case of a reduction in use and simultaneously rising temperatures)

- ecosystems in which climatic changes trigger cascade effects, e.g. heavy attacks by insects or other pests due to higher temperatures (such as three instead of two bark beetle generations per season)

### Measures, uncertainties, knowledge gaps

**Varied species composition and sustainable use increase the resistance and stability of natural ecosystems, and best ensure human living space. Climate change can be influenced only slowly. However, we can change the way we use our living space more quickly. In so doing, we can also much more rapidly achieve a sustainable effect in order to maintain the protective functions of ecosystems.**

In particular in the last 50 years, the settlement area in Switzerland has extended into topographically dangerous areas. Slopes that used to be forested, have been built on after forestry operations ceased. River valleys that were avoided for centuries, are intensely inhabited today. It is the vegetation (changed by humans) in particularly these exposed areas that is often no longer able to fulfil its protective function in the case of extreme events. Not only has global development brought with it anthropogenic climate change but it has also made people, in particular in mountainous areas like Switzerland, more dependent on living space security, which depends on intact vegetation cover. Technical measures will not be able to ensure living space security in Swiss mountain valleys without the assistance of natural ecosystems, especially of forests on steep slopes. It will

therefore be crucial to promote varied species composition of ecosystems appropriate to the location and to create near-natural age structure and tree-species composition in forests where this no longer exists. Whether this diversification can take place rapidly enough, is, however, rather doubtful in view of the slow developmental rate, particularly of forest ecosystems.

Awareness must be raised (politically) of the direct link between near-natural (that is, well adapted and diverse), resistant ecosystems and living space security in mountain areas. In this case, recognising that ecosystems always include the people living in them and that sustainable development can only be achieved in consideration of human activities is particularly important in a densely populated country like Switzerland.

## 4. Use and products of ecosystems

**Land ecosystems not only fulfil important functions such as living space security, they also provide economically relevant products like wood, food and clean water.**

In addition to the comprehensive benefit of securing living space already described in section 3 on natural hazards and living space security, land ecosystems also fulfil important functions outside intensive agriculture, such as air and water purification, carbon and water storage, and nutrient recycling. They provide economically relevant products like wood, food and water.

Furthermore, forests have a particularly high carbon sink potential due to the large biomass stock of trees; distinctly larger than that of grassland or fields (where the potential is consumed by humus). Although all these services and products are influenced by physical-chemical and climatic conditions, they have also been shaped substantially by land use for millennia.

### Development up to today

**In the past 100 years, most land ecosystems have been influenced more strongly by changes in land use than by climate change. Nevertheless, the effects of climate change on the supply of bioresources (e.g. hay, stock of wood, carbon storage) can already be observed in Switzerland.**

The land use of agricultural and forest ecosystems has changed strongly in the past 100 years. Intensification and mechanisation in agriculture have above all increased productivity considerably but have at the same time reduced humus and thereby carbon storage in agricultural soils.<sup>11</sup> The stock of wood in Swiss forests has substantially increased in the last decades and is at a maximum today, both per unit of area (minor use) as well as due to the increase in forest area. About 5 million m<sup>3</sup> of wood is cut per year in Switzerland, although 7 million m<sup>3</sup> of wood could be used, based on the annual growth, without any negative effects on forest stands. In the past 50 years, forests have also grown much faster than before as a result of increased atmospheric nitrogen inputs and favourable climate conditions. Today, 90% of the Swiss forests are oversupplied with nitrogen, which, apart from enhanced tree growth, leads to a decrease in base saturation in the soil, soil acidification and contamination of the leakage water that feeds the groundwater.

Impacts of climate change can already be recognised today in the earlier budding and thus in the extension of the vegetation period by 5–6 days.<sup>12</sup> In the recent past, extreme events have occurred more frequently (e.g. the Vivian and Lothar storms, heat wave summers, major

fires in the Valais) and have caused damage to forests.

The changes in use have taken a very different course depending on elevation. Whereas in valley sites in the past 10–15 years, extensification in addition to agricultural intensification has occurred, at the sub-alpine and alpine sites, extensification (conversion of meadows to pastures) dominates to the point of abandoning use entirely. These formerly cultivated areas become overgrown and forest moves in. If grazing is lacking above the mountain forest, more water than in the past is transferred into the atmosphere, due to evaporation and particularly transpiration of the now taller vegetation. Less water runs off (up to 10%), which can ultimately lead to reduced energy production in the catchment area of a hydroelectric power plant.<sup>13</sup>

Wetlands have been strongly changed by humans in the past 100 years.<sup>14</sup> Whereas in the past, they used to be significant water and carbon stores, many of them have been utilised for energy and agricultural production through peat cutting and drainage. As a result, wetlands in Switzerland have decreased in area by almost 90% in the last 100 years – associated with a large decrease in biodiversity and hydrological buffer areas.

## Looking ahead

**In the future, the functions and benefits of land ecosystems will be mainly influenced by a combination of effects, e.g. high temperatures combined with low precipitation. Water availability and the alpine region will be of particular relevance.**

The climate scenarios for Switzerland in 2050 are within a range that will lead to perceptible changes in the productivity of forests and permanent grassland. The previous trend towards higher productivity due to intensification will be weakened or limited by a pronounced water shortage in summer at high temperatures – such as in the year 2003. Ciais et al.<sup>15</sup> showed that in Europe in 2003, the carbon sink completely changed and European forests turned from carbon sinks into clear carbon sources. This can result in reduced carbon storage in soils, enhanced by the possible increase in decomposition of organic matter in humus<sup>16</sup> and the decrease in carbon inputs by the vegetation. Should – as models predict – such dry summers become more frequent, carbon storage in wood and soil would decrease in the long term. However, local effects strongly depend on what happens to soil moisture. Carbon storage will continue to increase due to the expansion and underusage of forest stands, as long as rising energy costs do not effect a return to wood as a resource. Increased tree growth due to higher

CO<sub>2</sub> concentrations is rather unlikely, since the supply of other essential nutrients (except for nitrogen) will not increase.<sup>17</sup> Water shortage in summer and autumn will mainly affect vale and hill country in the future. Water shortage will have less impact in high montane forests and at alpine elevations. Here, an increase in productivity is more likely. Water availability will thus become even more important in the future.

The cultivation of land ecosystems will have to adapt to changed environmental conditions (e.g. earlier hay harvest, irrigation of permanent grassland, adjustment of livestock, increased significance of high altitude areas for summer pasture, changes in the choice of tree species). Cultivation of higher altitudes to sustain livestock will likely become more lucrative again. That means that the alpine region will possibly become more important again as a rediscovered cultivation area as well as a retreat/replacement living space. However, this will only succeed if these areas are kept open by active management and the encroachment of meadows and pastures is stopped.

## Uncertainties, measures

**Adaptive forest and permanent grassland management is required in order to reduce or avoid the negative impacts of climatic changes on the benefits and products of these ecosystems. Alpine pasture land should be kept open.**

The natural variety of tree species should be fostered as a protection against climate change or the consequences of extreme events. Extensive clearing should be avoided and old forest stands should be changed into multi-layered forests (e.g. “Plenterwald” – uneven-aged selection forest<sup>18</sup>) in order to ensure stability and guarantee that the stored carbon is not released into the atmosphere as CO<sub>2</sub>.

Active management of the landscape, in particular in the alpine region, should include value-added aspects. The benefit can thereby be assessed for the entire society (also monetarily).

Political discussion must take place on how adequate sustainable management can/should be implemented and supported.

## Literature and notes

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